EFFECTIVE DATE	LANL-EES-4-DP-801, R2
October 16, 1996	Page 1 of 12

SINGLE-AND MULTIPLE-WELL TRACER TRANSPORT EXPERIMENTS IN THE FIELD

LOS ALAMOS

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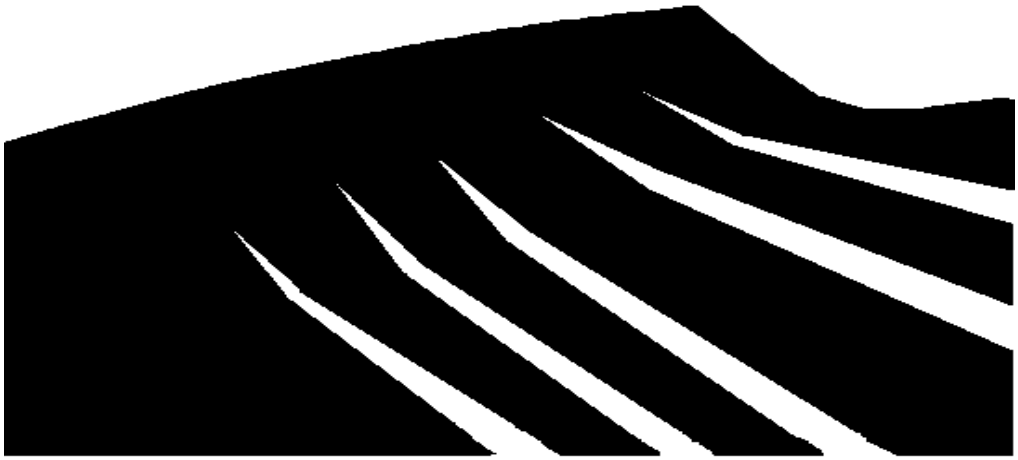

APPROVAL FOR RELEASE

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Los Alamos
Yucca Mountain Site Characterization Project

HISTORY OF REVISION

REVISION NO.	EFFECTIVE DATE	PAGES REVISED	REASON FOR CHANGE
R0	01/18/96	N/A	Initial procedure.
R1	05/10/96	5, 8, & 12	To address M&TE calibration and training requirements.
R2	10/16/96	All	Technical requirement revisions and minor non-substantive editorial changes.

SINGLE-AND MULTIPLE-WELL TRACER TRANSPORT EXPERIMENTS IN THE FIELD

1.0 PURPOSE

This detailed procedure (DP) describes the conduct of single-and multiple-well tracer transport experiments in the field. The procedure is intended for the C-Wells Reactive Tracer Testing Studies for the Yucca Mountain Project (YMP), but it could also be used for YMP tracer transport studies at other field locations.

2.0 SCOPE

This DP applies to any single-or multiple-well tracer transport experiment conducted in the field. It is beyond the scope of this DP to describe and/or provide instruction for all possible procedures that may be used to conduct field tracer transport experiments, so the user must document the work activities for each tracer experiment. This DP does not apply to the analyses of tracers collected in ground water samples during tracer transport experiments. Tracer analyses will be conducted in accordance with separate DPs that document the analytical process.

3.0 REFERENCES

LANL-YMP-QP-02.7, Personnel Training
LANL-YMP-QP-03.5, Documenting Scientific Investigations
LANL-YMP-QP-08.1, Identification and Control of Samples
LANL-YMP-QP-17.6, Records Management
YAP-SII.4Q, The Collection, Submission, and Documentation of Non-Core and Non-Cuttings Samples to the Sample Management Facility for Site Characterization.

4.0 DEFINITIONS

4.1 Tracer

Any species that is introduced to a hydrogeologic system for the purpose of studying ground water flow and/or species transport. To be effective, tracers should be readily distinguishable from constituents that occur naturally in the ground water, or they should be present at concentrations that significantly exceed background concentrations in the ground water.

4.2 Tracer Transport Experiment

An experiment in which one or more tracers are introduced at one or more locations into a ground water flow system, and then the concentrations of the tracers are measured as a function of time and/or location in the system. The

information obtained from such an experiment can provide insights into the hydrogeology of the ground water system being studied and/or into the transport characteristics of various species in the system.

4.3 Single-Well Tracer Experiment

A tracer transport experiment involving only one well. The single well is used as both an injection well and a sampling well. Single-well experiments are typically conducted either as injection-withdrawal tests (where tracer is injected into the well, chased with water and then the water flow is reversed to allow tracer recovery) or drift-pumpback tests (where tracer is injected into the well and allowed to drift with the ambient ground water flow, and then water is withdrawn from the well to allow tracer recovery).

4.4 Multiple-Well Tracer Experiment

A tracer transport experiment involving more than one well. Multiple-well tests can be conducted in a variety of modes depending on the number of wells involved and on whether some or all of the water withdrawn from a recovery well is reinjected into an injection well. Variations include, but are not limited to, (1) convergent tests, in which there is no reinjection of withdrawn water, (2) partial recirculation tests, in which a fraction of the withdrawn water is reinjected into an injection well, (3) complete recirculation tests, in which all withdrawn water is reinjected into an injection well.

5.0 RESPONSIBILITIES

The following personnel are responsible for the activities identified in Section 6.0 of this procedure.

- The Principal Investigator (PI)
- Users of this Procedure

6.0 PROCEDURE

The use of this procedure must be controlled as follows:

- If this procedure cannot be implemented as written, YMP personnel should notify appropriate supervision. If it is determined that a portion of the work cannot be accomplished as described in this DP, or would result in an undesirable situation, that portion of the work will be stopped and not resumed until this procedure is modified, replaced by a new document, or current work proactive is documented in accordance with OP-03.5, Section 6.1.6.

- Employees may use copies of this procedure printed from the controlled document electronic file; however, employees are responsible for assuring that the correct revision of this procedure is used.

- When this procedure becomes obsolete or superseded, it must be destroyed or marked “superseded” to ensure that this document is not used to perform work.

6.1 Principle

Single- and multiple-well field tracer transport experiments are carried out for a variety of purposes, which include (1) obtaining estimates of ground water travel times under forced gradient conditions, (2) obtaining estimates of key parameters for performance assessment models of contaminant transport, and (3) validating conceptual models that describe the transport of sorbing and nonsorbing solutes and colloids in various hydrogeologic settings. The common theme in all tracer transport experiments is that a known mass of one or more tracers is introduced into a ground water system at specific locations, times, and rates, and then the concentrations(s) of the tracers are subsequently measured at other locations and/or times in the system. The tracer concentrations as a function of time and location yield information about transport mechanisms and parameters, thus helping to meet the objectives stated above.

6.2 Equipment and Hardware/Software

The hardware used in field tracer transport experiments can include many items and will depend on the type of test being conducted. Hardware may include, but is not necessarily limited to: pumps and associated flow rate control equipment, tracer injection equipment, inflatable packers/packer strings, down-hole instrumentation (e.g., pressure and temperature transducers), data acquisition/logging systems, electrical power generation and distribution systems, ground water sampling systems, down-hole and surface piping, storage tanks, and flow meters. The data acquisition/logging system will typically include a computer and associated data acquisition/reduction software.

NOTE: At the C-Wells, much of this equipment may be purchased and/or operated by YMP participants other than Los Alamos (e.g., the USGS). Los Alamos may be unable to control the use of such equipment, so we will obtain a record of all relevant actions and measurements taken by the other participants that are critical to the conduct and interpretation of tracer experiments (see also subsection 6.3.2). Data critical to the tracer experiments, which was gathered using equipment whose calibration cannot be substantiated, will be evaluated and qualified by the PI before use.

6.2.1 Equipment Malfunctions

Malfunctions of any of the major equipment associated with a tracer transport experiment should be immediately or very quickly apparent

to the DP user (e.g., pump failure, power failure, malfunction of sample collection equipment). In most cases, malfunctions of such equipment will cause test interruptions or the inability to automatically collect samples for some time period. However, minor equipment malfunctions may go unnoticed for some time, particularly if they occur at night when few or possibly no personnel are present at the test site. Equipment malfunctions will not necessarily render the results of a tracer test uninterpretable, and, in most cases, the test should not be aborted unless there is a safety consideration or a clear reason that the test results cannot be interpreted. For instance, the failure of a pressure or temperature transducer will have minimal impact on the analysis and interpretation of a tracer test, and the test should not be aborted. There are at least two reasons why tracer tests should be completed if possible: (1) field tests are very expensive, so even if a test has less-than-ideal control or instrumentation, it is better to get as much information as possible out of the test than to simple abort the test, and (2) tracers should be flushed from the ground water system to the greatest extent possible to avoid cross-contamination with subsequent tracer experiments in the system. The PI and DP users should make judgments regarding the impact of any equipment malfunctions on a test. The equipment malfunctions and any subsequent actions to correct them should be clearly documented in a field notebook. Notebooks should be kept in accordance with QP-03.5, Documenting and Scientific Investigations.

6.2.2 Safety Considerations

Tracer transport tests in the field typically involve the use of heavy equipment and electrical power distribution systems that include on-site generation of power with diesel generators. Hard hats and safety shoes are required to be worn at most sites. Heavy equipment should be operated only be personnel who are properly trained in the procedures for using the equipment. All on-site personnel should be aware of and avoid electrical hazards. Work should be conducted at night only if there is adequate lighting to ensure hazard recognition and avoidance. Depending on the test procedure, there may be special hazards associated with each specific test (e.g., sampling of pressurized lines the use of high-pressure gas cylinders, handling of tracers that are hazardous). All potentially affected personnel should be advised of any special hazards prior to each test.

6.2.3 Special Handling

Handling of equipment and hardware/software should be done in accordance with manufacturer's or vendor's guidelines. Special handling of equipment or hardware should be considered on a case-by-case basis as the need arises. Any special handling should be documented in a field or laboratory notebook.

6.3 Preparatory Verification

Preparatory verification for single- and multiple-well tracer transport experiments in the field depends on the type of test being conducted, and it must be done on a case-by-case basis. In multiple-well experiments, it is generally desirable to have a steady-state or near-steady-state flow field established prior to introducing tracers to the ground water system. That is, pressure transients caused by pumping should have decayed to the point where pressures are no longer changing significantly. Also, it is desirable to establish that the pump flow rate(s) are not varying significantly before introducing tracers. In single-well injection-withdrawal tests, the flow conditions will necessarily be transient, so these criteria do not apply. In some cases, it may be desirable to conduct multiple-well tracer tests under transient conditions. In these cases ,it will be more important to measure and record what the pressure and flow conditions are with time than to establish certain conditions prior to the tracer test. It is also generally desirable to purge the production well prior to a tracer test by pumping out at least five borehole volumes of water (this can be accomplished in multiple-well tests during the establishment of steady-state conditions). The PI or DP user will be responsible for deciding what conditions are necessary before initiating a tracer test. The bases for a decision to start a tracer test should be documented in a field or laboratory notebook.

6.3.1 Hold Points

For most multiple-well tracer transport experiments, tracers should not be injected into the ground water system until pressures and flow rates under pumping conditions are no longer significantly changing (i.e., a steady-state is established). It is beyond the scope of this procedure to specify exactly what constitutes a significant pressure or flow rate change, as this will be system- and test-dependent. The PI or DP user will ultimately decide when tracers should be injected and then document the bases for this decision. This documentation could include pressure and/or flow rate data prior to tracer injection. For tracer tests in which a steady-state is not required, a “hold point” is not strictly applicable, although the PI or DP user should document the conditions prior to and during the experiment.

6.3.2 Calibration

The PI shall identify in a field or laboratory notebook all measurements that are critical to the conduct and interpretation of a test. Also, the PI shall identify what measuring and test equipment must be calibrated and what equipment need not be calibrated. All measuring and test equipment identified as requiring calibration should be calibrated (and calibration should be documented) in accordance with a YMP Quality Assurance Program. For Los Alamos-controlled equipment, the applicable QA procedure that addresses calibration is QP-12.3, Control of

Measuring and Test Equipment and Standards. However, at the C-Wells, much of the measuring and test equipment may be controlled by YMP participants other than Los Alamos (e.g., the USGS), so calibration of this equipment will generally not be conducted by Los Alamos. In such instances, Los Alamos will obtain a copy of all pertinent calibration records from the other participants. Pertinent calibrations will vary from test to test, but they could include calibrations of (1) balances, (2) flow rate measurement devices, (3) pressure measurement devices, and (4) temperature measurement devices. Some of these devices can only be calibrated before and after a test (or series of tests), so it is important to obtain records for calibrations conducted both before and after tests when applicable. Any analytical instrumentation used for tracer analyses will be calibrated in accordance with separate DPs that cover the operation of the analytical equipment.

6.3.3 Environmental Conditions

Environmental conditions (other than flow rates) typically cannot be controlled in field tracer transport experiments. However, it is often desirable to measure such variables as pressures and temperatures as a function of location and time before and during a test to aid in the interpretation of the test.

6.4 Control of Samples

Ground water samples collected during tracer transport experiments are to be identified and controlled in accordance with QP-08.1, Identification and Control of Samples. This procedure required that all samples be assigned bar codes/identification labels obtained from the YMP Sample Management Facility in accordance with YAP-SII.4Q. If samples are split into separate aliquots (see below), each aliquot should be labeled such that it is traceable to the original sample collected.

Ground water samples that potentially contain tracers should be stored in such a way that evaporation of water is minimized or eliminated during storage (e.g., by storing them in tightly capped bottles and refrigerating them). They should also be stored such that the impact of storage on the analyses of tracers is minimized. For example, if a UV light sensitive tracer is used (e.g., a fluorescent dye such as fluorescein), the samples should be stored in darkness or in UV opaque bottles. Samples containing colloid-tracers should generally be stored in glass bottles as opposed to plastic bottles to minimize deposition of the colloids on the container walls. If sorbing tracers (generally cations) are used in tracer tests, it is often desirable to split the collected samples and acidify one of the aliquots with a drop or two of concentrated acid (HC1 or HNO_3) to prevent sorption to container walls or precipitation. If there is any question about sorption to container walls, batch sorption experiments should be conducted (and documented in a laboratory notebook) using the tracers and lab-ware in question. Special storage and handling requirements for different tracers should

be considered on an individual basis, and the storage and handling of all tracer-containing or potentially tracer-containing ground water samples should be documented in a laboratory notebook so that a sample history is maintained. This documentation should be done in accordance with QP-08.1.

6.5 Implementing Procedure

6.5.1 Conduct of Tracer Tests

Because of the many different ways that tracer tests can be conducted (see sections 4.3 and 4.4), it is not practical to specify a step-by-step procedure that applies to all tracer tests. Rather, it is the responsibility of the PI or the DP user to document the work activities for each test. This documentation should be maintained in a field or laboratory notebook or in an attachment to such notebook. Specifically, the PI or DP user should document the following for each test (some of this documentation may consist of copies of records generated by other YMP participants):

- which measurements are critical to the conduct and interpretation of the test (see Section 6.3.2),
- which measuring and test equipment must be calibrated, and which measuring and test equipment need not be calibrated during the test,
- unique identifiers of all Measuring and Test Equipment that the PI identifies as requiring calibration,
- calibrations of Measuring and Test Equipment that are conducted during the course of the test (e.g., equipment that is calibrated at each use),
- all measurements that the PI has identified as being critical to the conduct and interpretation of the test (see Section 6.3.2),
- locations of packers in boreholes and status of packers during the tracer test (inflated or deflated)
- well purging procedures (if applicable), and times and methods of collection of ground water samples for background water chemistry determination,
- bases for initiating tracer injection (e.g., pressures and flow rates stabilized to within x%),
- identity and mass of tracers injected, and approximate volume of solution that tracers were mixed with prior to injection (includes measurements of weights and volumes),

- method(s), location(s), time(s), and rate(s) of tracer injection into the system, including the volume and injection rate of any water used to chase tracer solution into a borehole (typically in a non-recirculating test),

- any unusual occurrences (and the time at which they occurred) such as a pump failure, sample collector malfunction, failure of a pressure or temperature measurement device, loss of a packer, or any other event that could affect the interpretation of the test,

- unique identifier, collection location, collection time, special treatment (e.g., sample splitting and acidification of one aliquot) and storage location of all ground water / tracer samples taken during the test (sample identification and control are done in accordance with QP-08.1).

This list is not intended to be all-inclusive. Any additional information that might be useful in the interpretation of tracer tests should be documented in a field notebook along with the information listed above.

NOTE: It is generally desirable to collect / hold back a small aliquot of the tracer material (e.g., a powder or solution) that is injected into the ground water system and to sample the packed-off interval that the tracer solution is injected into as a function of time during the experiment. It is also desirable to sample the injection zone after the completion of an experiment to determine the amount of tracer that remained in the injection borehole during the test. These samples will help define the "source term" as a function of time during the tracer test, and they will also help establish a mass balance for the experiment (both of which will greatly aid in the interpretation of a test).

6.5.2 Tracer Concentration Measurements

Documentation of tracer concentration measurements will be done in accordance with DPs that cover the operation of the appropriate analytical equipment.

6.6 Data Acquisition and Reduction

Methods of data acquisition and reduction should be documented in a field or laboratory notebook or in a final report that documents the results of a tracer test. The acquired data (in conjunction with tracer concentration measurements in ground water samples and the known configuration of the system) are ultimately used to interpret the tracer tests. Potential sources of uncertainty and error associated with data acquisition should be controlled by one or more of the following methods: (1) using Measuring and Test Equipment that has been calibrated in accordance with a YMP QA Program, or equivalent (2) using manufacturer's specified tolerances for accuracy and precision (if a device

cannot be directly calibrated when in service, which is sometimes the case with down-hole instrumentation), and/or (3) doing repeat measurements (if possible) to obtain a population of readings from which precision can be estimated by statistical analysis (e.g., standard deviation).

Data acceptance criteria cannot be established in this DP because these criteria will depend on many factors associated with each tracer test. In some cases, it may be necessary to reject a portion of a data set from a tracer experiment (e.g., when a measuring device fails or malfunctions), but the balance of the data set can and should still be accepted because of the prohibitive time and cost associated with repeating tracer experiments. In these cases, the PI must make judgments about the impact of the rejected data on the interpretation of the test, and the interpretation may have to be modified, caveated, or have greater uncertainty bounds placed on it accordingly. The PI ultimately reviews all data and records associated with each tracer test and determines the acceptability of the data. The PI may reject data for any of the following reasons:

- anomalous results,
- operational deviations which call into question the accuracy of the results (e.g., equipment malfunctions or failures), and
- inadequate record keeping.

The identity of the rejected results and the basis for rejection are recorded in a laboratory notebook.

Acquisition, reduction, and acceptance of data resulting from analyses of tracers are addressed in separate DPs that cover the operation of the analytical equipment.

6.7 Potential Sources of Error and Uncertainty

If a problem arises that can be considered a potential source of error or uncertainty in a tracer test, the PI or DP user should document it in a field or laboratory notebook. The PI or DP user can then later assess the impact of the source of error or uncertainty when interpreting the test. Sources of error and uncertainty related to data acquisition and reduction are discussed in section 6.6. Examples of other types of errors and uncertainties in tracer tests include (but are not limited to): (1) contamination in sample collection containers, (2) cross-contamination from previous tracer tests in which tracers were not fully flushed from the ground water system, and (3) error and uncertainty in knowing the properties and characteristics of the ground water system in which the test is being conducted, which can lead to ambiguous or erroneous interpretations of the test data.

7.0 RECORDS

Records generated as a result of this DP are entries in field or laboratory notebooks or attachments to such notebooks. The documentation should consist of any applicable items identified in Section 6.0. For convenience, a separate field notebook may be kept

for each tracer test that is conducted. These notebooks can effectively be used as log books for each test. Notebooks should be kept in accordance with QP-03.5, Documentation of Scientific Results.

All records should be submitted to the Records Processing Center in accordance with QP-17.6, Records Management.

8.0 ACCEPTANCE CRITERIA

Proper completion and submittal of the records described in Section 7.0 constitutes the acceptance criteria for this procedure.

9.0 TRAINING REQUIREMENTS

Read-Only training is required for this DP. Training is documented in accordance with QP-02.7.

10. ATTACHMENTS

(N / A)